The authors thank this reviewer for the many very constructive and helpful comments. Below we outline the answers to all questions and how we plan to improve our manuscript (ms) in response to these comments.

We will refer to the ms published in BGD as the original ms, and all figure and table numbers refer to the original ms unless otherwise noted. Please note that we plan to remove the STD configuration in our revised ms. QM will be taken as the new STD configuration in the revised ms, hence there will be no configuration designated as QM in the revised ms.

Comment: This paper addresses the problem of biogeochemical models simulating complete depletion of nitrate in oxygen minimum zones, while observations show that complete depletion does not take place. The problem is addressed using a box-model of the Eastern Tropical South Pacific and investigated which processes that could be responsible for the discrepancy. The authors are able to produce the wanted effect by reducing the remineralization rate and thus indicate to how global biogeochemical models can be altered to account for this process. The model is tested with a varying degree of ventilation with the surrounding ocean regions, quadratic mortality, allowing nitrogen fixers to take up NO_3^- and reduced denitrification. This is an interesting paper that also demonstrate how box-models is a powerful tool for investigation ocean processes.
Response: We thank the reviewer for the general positive evaluation and thereafter will concentrate on questions and suggestions to improve our original ms.

Comment: My main concern with this paper the lack of systematic testing of the other parameters in the model, if the model sensitivity that been tested in previous publications it should be stated clearer. As previous optimization studies has shown biogeochemical models can give similar results with different combinations of parameters and I therefore think a systematic sensitivity analysis should be performed, unless previous publications can be cited.
Response: There are 13 parameters in total for our biogeochemical model now (listed in Table 5, M is omitted since the old STD configuration is removed from the revised ms). We have mainly focused on parameters that could be significant for the nitrogen cycle in the OMZ and potentially affect our conclusions. The parameters for the stoichiometry of C, N, P and O_2 are r_a, r_c, r_{den} and r_p. μ, μ_{NF}, M_q, N_h and P_h are parameters responsible for growth of both OP and NF. The remineralisation fractions f_U, f_{UM}, f_S, and f_I determine the fractions of exported production remineralised in different boxes. We now address the sensitivity of our model to the uncertainty in these parameters as follows. We add the following paragraph at the end of the new Section 2.5 (Sensitivity experiments):
"The literature ranges in Table 5 provide only a rough guide for the biogeochemical parameters. The sensitivity of r_p, μ, μ_{NF}, N_h and P_h is tested by changing each of them in the OBRD configuration according to the literature range. Effects of changing the remineralisation fractions f_U, f_{UM}, f_S, and f_I are examined by redistributing remineralisation between the U and UM, and S and I boxes (see Fig. 5 for details)."
The following paragraph is added at the end of the new Section 3.3 (Model sensitivity experiments). Accordingly, We will replace Fig. 5 with Fig. 1 of this response letter. :
"Varying biogeochemical parameters affects individual model predictions but not our main conclusions. The strongest effects are those of varying r_p and the remineralisation fractions (f_U, f_{UM}, f_S, and f_I) (Fig. 5). Lowering r_p to 12 increases N_{UM} by about 35%, but cannot change the strength our model domain being a NO_3^- source. Increasing r_p to 20 decreases N_{UM} by about 18%, but triples the strength of our model domain as a NO_3^- source. However, observations indicate that r_p is more likely to be higher than lower compared to the Redfield N:P ratio of 16 [Franz et al., 2012]. Increasing μ_{NF} to $1/2\mu$ results in higher N_{UM} concentrations and our model domain being a larger NO_3^- source. Intuitively, decreasing μ_{NF} to $1/4\mu$ results in lower N_{UM} concentrations and our model domain as a smaller NO_3^- source. Varying N_h results in virtually unchanged results. N_{UM} increases when changing remineralisation fractions in the intermediate boxes (f_{UM} and f_I) from 70% to 50% and 30% respectively, effectively lowering export production via lowering the export ratio. Nevertheless the qualitative behaviour of the model remains the same in these sensitivity experiments."

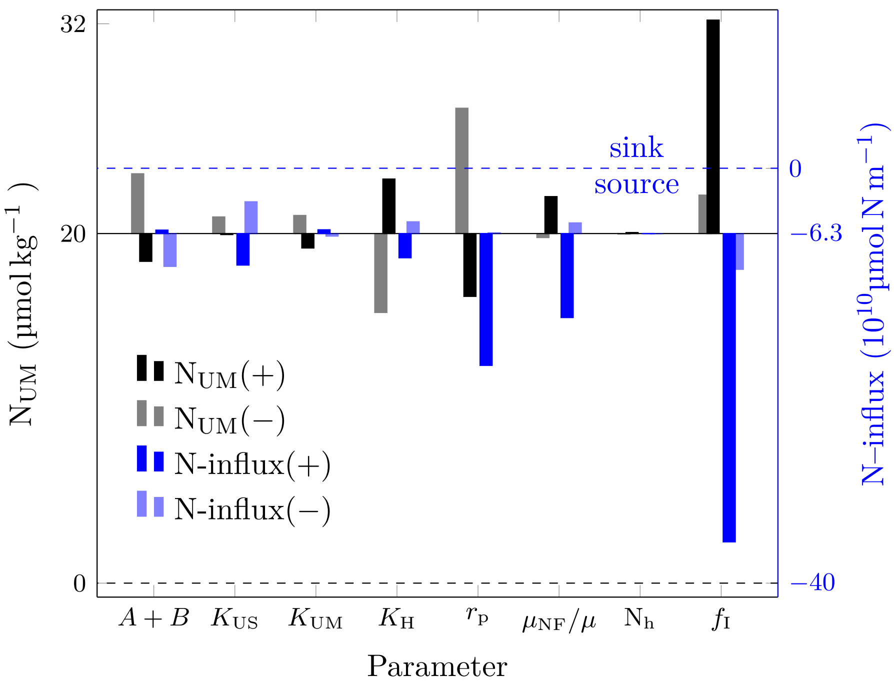


Figure 1: Sensitivity of NO_3^- concentration in the OMZ (N_{UM}) and the net NO_3^- flux out of the model domain to variations of the individual parameters describing ocean transport and biogeochemical processes (see Tables 2,5 and Fig. 1 for a description of the parameters). Black and blue bars represent changes in N_{UM} and N-influx, respectively. "+" and "−" indicate the response to increased and decreased parameters. Physical circulation parameters are varied by ±50%. r_P is varied between 12 and 20. μ_{NF}/μ is varied between 1/4 and 1/2. Nh varies between 0.3 and 0.9 µmol kg^{-1}. For f_i, "+" indicates f_U=f_S=60% and f_{UM}=f_I= 30%, and "−" means 40% and 50%, respectively.

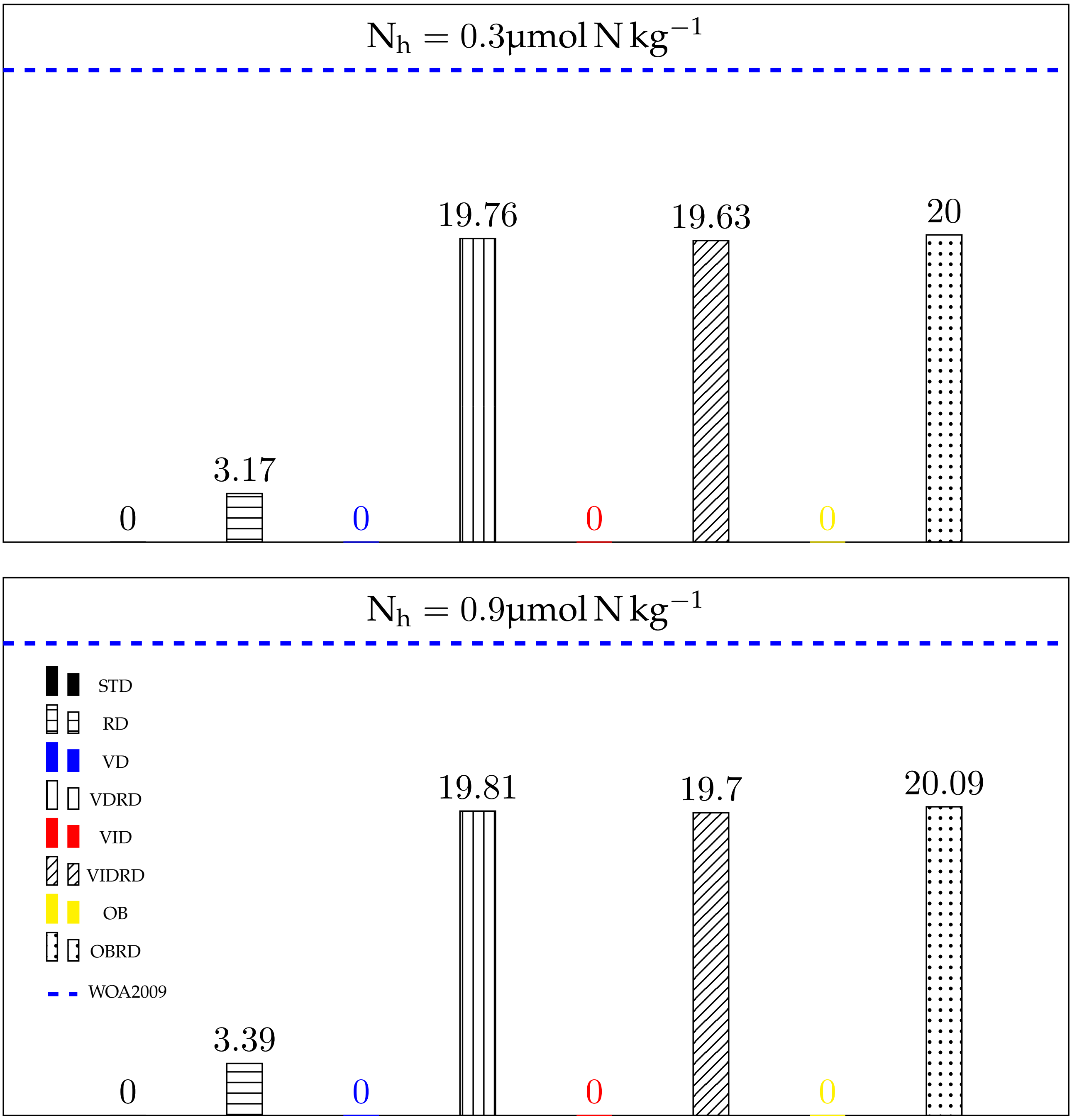
For detailed results of these sensitivity experiments in all model configurations, see also Fig. 2 of this response and our replies to the comments about deviations from Redfield ratio, confidence about NF growing at 1/3 of OP, and confidence about the remineralisation fractions, below. Fig. 2 of this response letter indicates that our main conclusions stay virtually unchanged for different N_h.

Comments: I also find that the composition of the paper is confusing, the authors jump back and forth among different runs, the paper could be made clearer with better structure (see suggestion below). The figures show a lot of information and I think the authors could get the message of the paper better across if they are more selective with the figures, for example reduce the number of panels to show fewer model variables, but focus on the ones most discussed in the text.
Response: We thank the reviewer for pointing out the lack of clarity in our original ms, which we will address more carefully in the revised ms. We describe how we plan to change the composition of our original ms below in response to this comment "The paper presents the 7 main model configurations summarized in table 4, but in between other experiments with sensitivity to different parameters are also described in the result section and a couple more appear in the discussion. The paper would be easier to read if these runs were described separately from the runs in table 4, for example under a sub-heading "3.3 Sensitivity run".", and the figures will also be changed accordingly.

Comment: In general, when results from other literature is mention it is useful to add information about how the results where obtained, was it model or observation (what kind?), was it the same OMZ-region? (For example top of p11097)
Response: Thanks for reminding us about pointing out the conclusions from either models or observations. We will **reword** these statements in the revised ms to make them clearer:

1, The top of P11097: Estimates derived from both field data and model analyses for the global oceanic fixed-N budget range from sources roughly balancing sinks [Gruber and Sarmiento, 1997,

Figure 2: NO_3^- concentrations in the UM box for the sensitivity experiments for N_h.



Gruber, 2004, Eugster and Gruber, 2012, DeVries et al., 2013], to a rather large net deficit between 140 and 234 $TgNyr^{-1}$ [Codispoti et al., 2001, Galloway et al., 2004, Codispoti, 2007].

2, P11097 L15-L18: OMZs currently account for only about 8% of the global ocean area but observations of intense denitrification and anammox in the OMZs indicate that they could be responsible for 30–50% of the total fixed-N loss [Gruber and Sarmiento, 1997, Codispoti et al., 2001, Dalsgaard et al., 2005, Paulmier and Ruiz-Pino, 2009].

3, P11098 L1-L2: Although alternative explanations for these nutrient patterns have been proposed in models [Mills and Arrigo, 2010], direct measurements have confirmed the occurrence of nitrogen fixation in and above the OMZ ofF the ETSP [Fernandez et al., 2011].

4, P11099 L2-L5: Anammox has recently been reported as another major pathway for fixed-N removal [Kuypers et al., 2005, Hamersley et al., 2007, Molina and Farás, 2009], but the relative contributions of anammox and denitrification are still a matter of debate [Ward et al., 2009, Bulow et al., 2010].

5, P11112 L16-L18: This strong control of the N cycle by phosphate is similar to the finding of previous models [e.g. Lenton and Watson, 2000, Canfield, 2006], where the occurrence and extent of oceanic anoxia was also tightly linked to phosphate supply.

6, P11113 L17-L20: Ganachaud and Wunsch [2002] estimated a net northward NO_3 transport of 270 ± 170 kmol s^{-1} (119.2 ± 75.1 Tg N yr^{-1}) across 17°S into the ETSP in a geostrophic inverse box model, which indicates that the ETSP is a net nitrogen sink, but their estimate included benthic denitrification, which is not accounted for in our current analysis.

7, P11113 L23-L25: From an ocean circulation-biogeochemical model-based analysis of nutrient concentrations and transport rates, Deutsch et al. [2007] estimated nitrogen fixation rates in the Pacific Ocean of about 95 Tg N yr^{-1}, half of which was speculated to occur in the ETSP.

8, P11113 L28-L29: More recently, Eugster and Gruber [2012] probabilistically estimated nitrogen fixation and water-column and benthic denitrification separately in their box model, which appears to be consistent with our results as their results also indicate that the water column of the IndoPacific is a large fixed-N source for that region.

Comment: Confidence about the nitrogen fixation being 1/3 of the maximum growth rate for phytoplankton.
Response: The lower maximum growth rate of nitrogen-fixation phytoplankton (NF) compared to ordinary phytoplankton (OP) has been observed in both lab cultures and physiological models. It is attributed mainly to the high energetic cost associated with fixing N_2 and also to more severe temperature limitation [LaRoche and Breitbarth, 2005, Breitbarth et al., 2007, Grimaud et al., 2014], and this will be mentioned in Section 2.2 (Biogeochemical model). But the exact ratio of maximum growth rates for NF and OP is unclear. Now we present sensitivity experiments with nitrogen fixation being 1/2 and 1/4 of the maximum growth rate for the OP in all model configurations. Still, our conclusion remains valid that NO_3^- depletion in the OMZ can be prevented only if the remineralisation rate via denitrification is slower than that via aerobic respiration (Fig. 3 of this response letter). The only problem is that NO_3^- inventory in our model domain can not reach steady-state in the VDRD and VIDRD configurations when the nitrogen fixation rate is 1/2 of the maximum growth rate for OP, but this does not happen in our most realistic configuration (OBRD). This problem can be solved by including the facultative N_2-fixation, where NF can take up NO_3^- under hight ambient NO_3^- conditions.

Currently, many global biogeochemical models include a temperature-dependent growth rate for NF [Schmittner et al., 2007, 2008, Keller et al., 2012, Landolfi et al., 2013], e.g., Schmittner et al. [2008] use a maximum growth rate for the NF of about 13.7% to 31% of that for OP for temperatures between 20 and 30°C (Fig. 4 of this response letter), which is even lower than our estimate.

Comment: Confidence about the remineralization rate in the different boxes?
Response: For our biogeochemical model, we assume a fixed remineralization rate in different boxes. A brief justification has been given in caption (b) of Table 5. According to Suess [1980] and Martin et al. [1987], about 92% and 97% of the total primary production are remineralised in the top 500m of the ocean, and we applied 90% in our model. About 20% regeneration is needed in the surface box to allow coexistence of the OP and NF. We have now performed sensitivity experiments to test the effects of different remineralization rates. Our conclusion that the reduced denitrification rate is the main mechanism in preventing NO_3^- depletion in the OMZ is robust no matter whether there are 40% and 50%, 50% and 40%, or 60% and 30% primary production remineralized in the surface and intermediate boxes, respectively (Fig. 5 of this response letter). But the nitrogen inventory of our model domain can not reach steady state when the remineralisation ratios are 50% and 40%, or 60% and 30% in the VDRD and VIDRD configurations, where nitrogen fixation exceeds fixed-N loss via denitrification, leading to an ever increasing fixed-N inventory in the model domain. Still, this problem can be solved by including facultative N_2-fixation and does not occur in the most realistic configuration (OBRD).

Comment: What about deviations from the Redfield ratio in terms of nutrient uptake, the ability of some organisms to utilize organic phosphorous?
Response: We have now tested the response of our model to deviations from the Redfield Ratio in

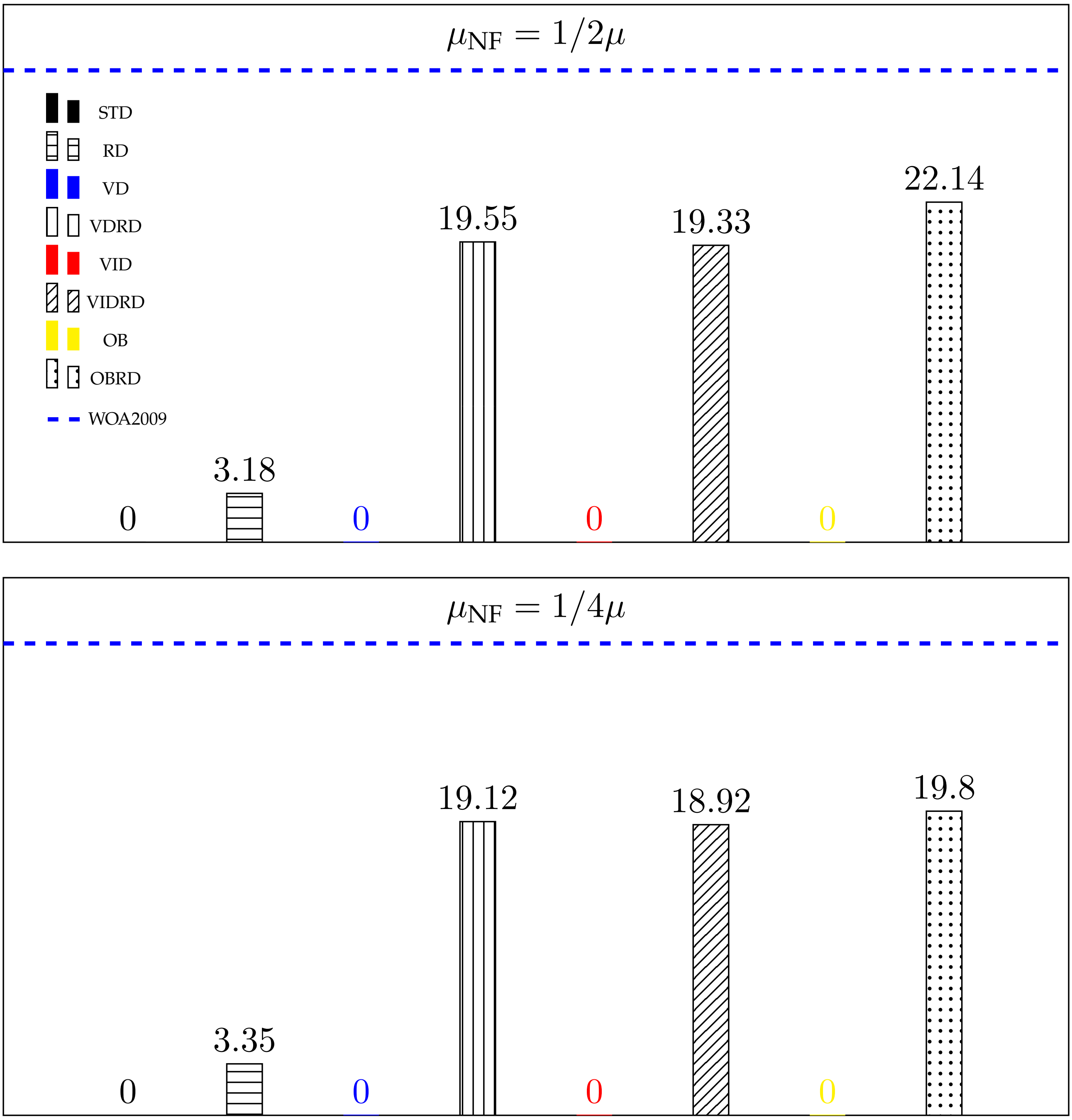
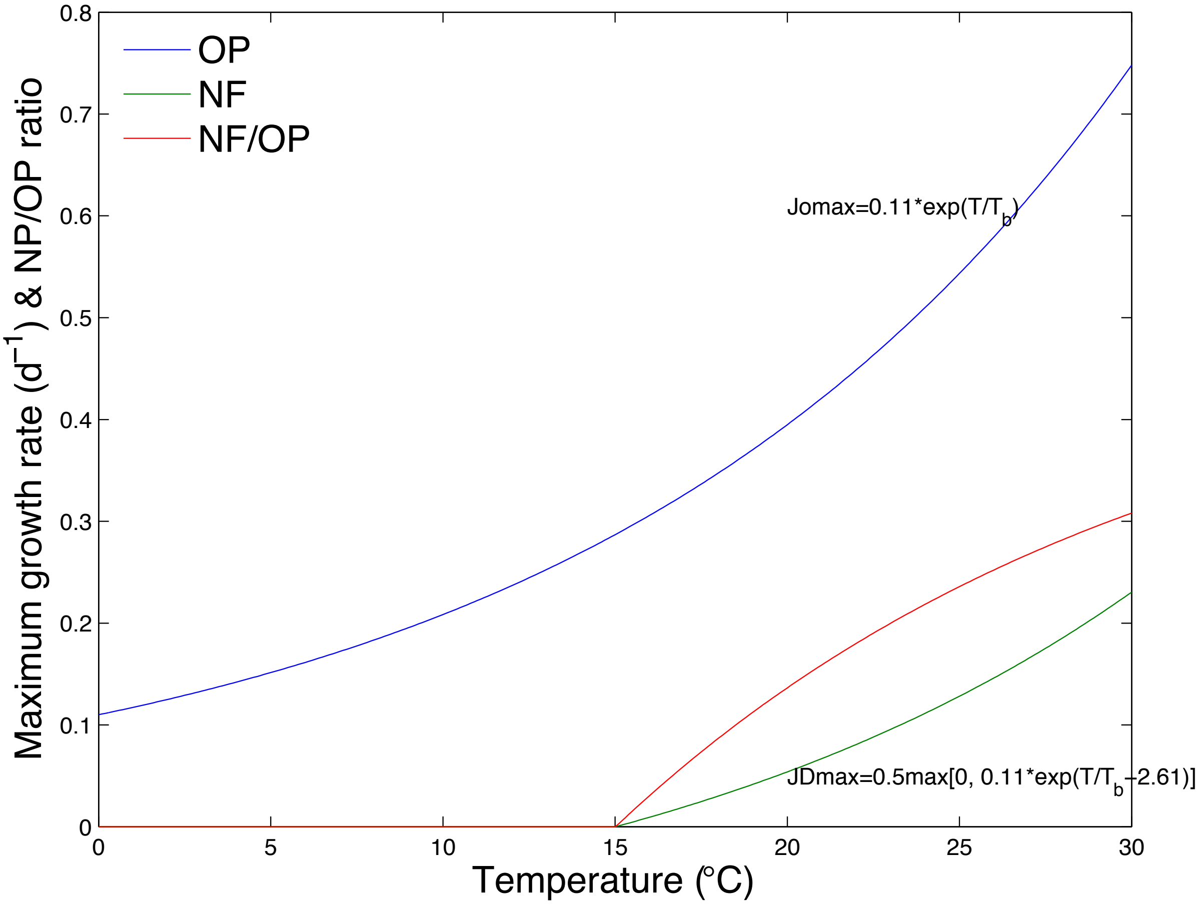


Figure 3: NO_3^- concentrations in the UM box for the sensitivity experiments for u_{NF}. The NO_3^- concentration in the OMZ in the VDRD and VIDRD configurations of the top panel is from the facultative N_2-fixation.

terms of nutrient uptake. Since phytoplankton can have different N:P uptake ratios in different OMZs, <16 in the Western Africa but >16 in Peru [Franz et al., 2012], we have tested N:P $=$ 12 and N:P $=$ 20 respectively for both OP and NF in our model. Also, because higher N:P ratios (>16) for diazotrophic phytoplankton are found to better agree with the observations both in experiments [Sańudo-Wilhelmy et al., 2004] and models [Klausmeier et al., 2004], we have made another sensitivity run with N:P $=$ 12 for OP and N:P $=$ 25 for NF. We are confident with our conclusion that the reduced denitrification rate is the main mechanism to prevent NO_3^- depletion in the OMZ, because this conclusion does not change (Fig. 6 of this response letter). We find that the oxygen conditions can vary slightly with different uptake ratios (figure not shown).

While the ability to utilise organic P has been proposed as an advantage of diazotrophs [Houlton et al., 2008, Ye et al., 2012], ordinary phytoplankton can also use DOP [e.g., Chu, 1946, Cotner, Jr. and

Figure 4: Maximum growth rate estimated from the Schmittner (2008) model.



Wetzel, 1992] and a clear advantage of diazotrophs over ordinary phytoplankton in the presence of DOP has never been demonstrated. Thus, we treat all available P to phytoplankton operationally as $PO_4{}^{3-}$ and assume that all organic phosphate is remineralized to $PO_4{}^{3-}$. We will clarify this in Section 2.2 (Biogeochemical model) of the revised ms.

Comment: In table 5: two parameters (U_{NF} and M) have been set outside the range given in the column to the right. Could an explanation for this be added to the text?
Response: The U_{NF} range in Table 5 refers to the maximum rates obtained at the optimal temperature for each species, but the annual average temperature in our U box is only about 19°C, which is much lower than the optimal temperature (≈ 27°C) of diazotrophs. Considering the strong temperature sensitivity of diazotrophy [e.g., Breitbarth et al., 2007], our U_{NF} value is well within the temperature-corrected literature range. We will clarify this in the revised ms.

For simplicity, we use the same linear mortality for ordinary and diazotrophic phytoplankton in the STD configuration of the original. M has been removed from the model, as all configurations now employ quadratic mortality terms.

Comment: Explain how gu and gs were determined.
Response: A brief introduction about how g_U and g_S were determined was given in Appendix C of the original ms.
^{14}C data were employed to calibrate the physical parameters of our model. We have 7 parameters to

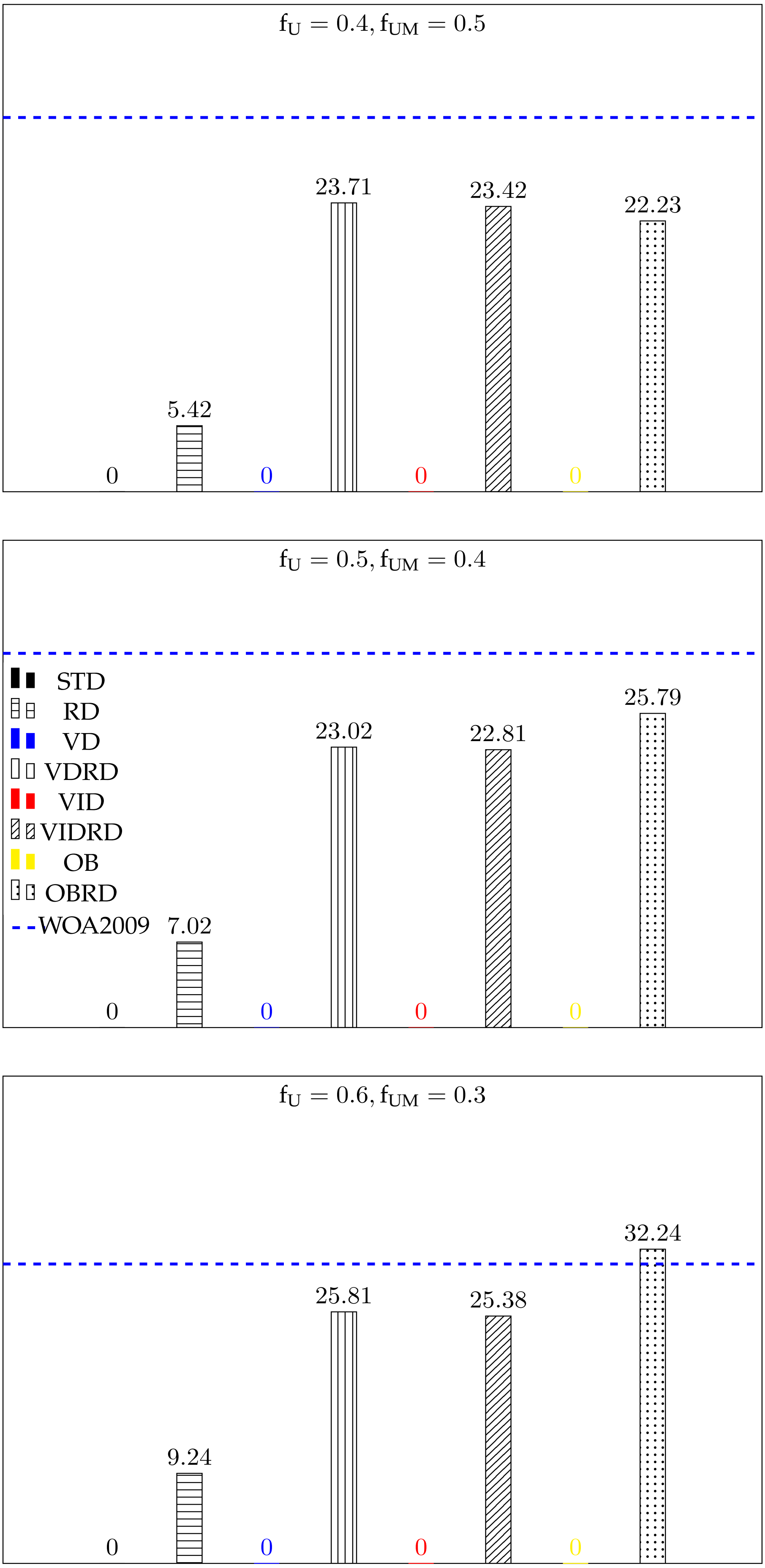


Figure 5: NO_3^- concentrations in the UM box for the sensitivity experiments for f_U, f_S, f_{UM} and f_I. The NO_3^- concentration in the VDRD and VIDRD configurations of the last two panels is from the facultative N_2-fixation, which can prevent the unsteady state problem.

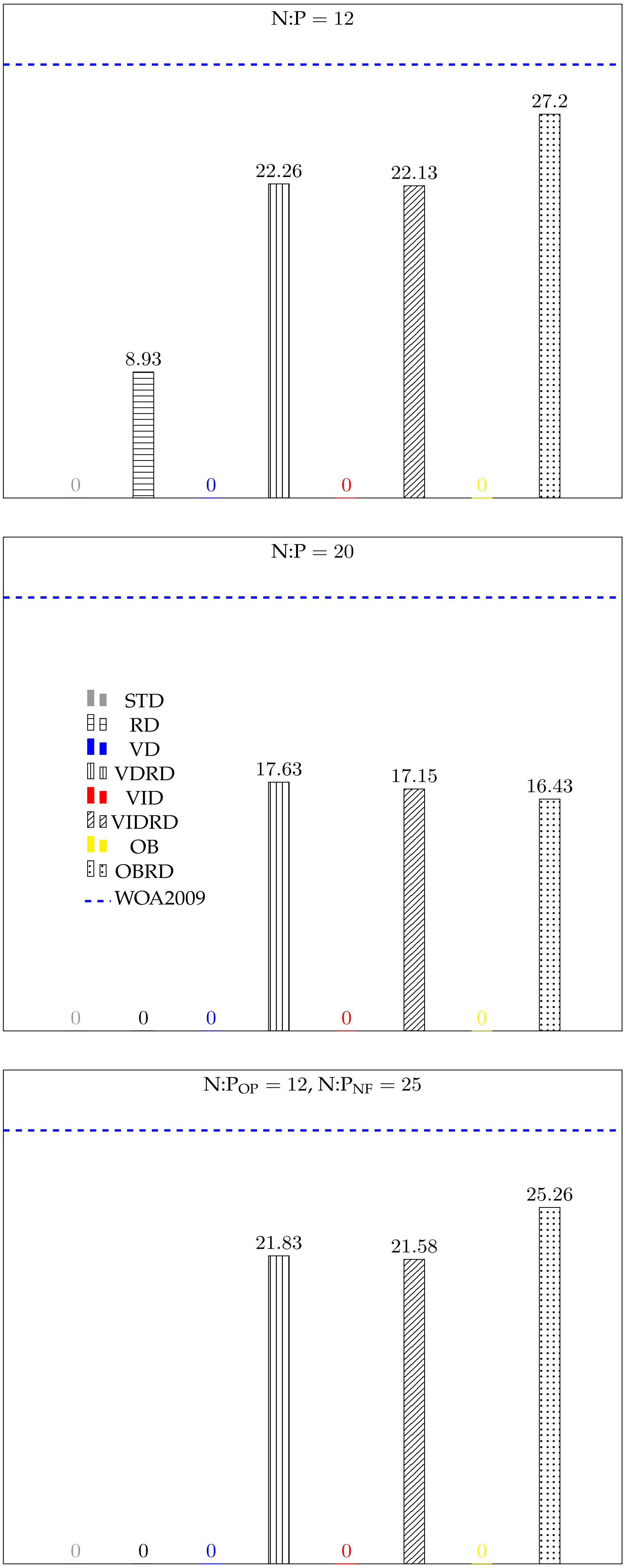


Figure 6: NO_3 concentrations in the UM box for sensitivity experiments for deviation from the Redfield ratio.

be determined (listed in Table 4), but there are only 5 linear equations representing transport and SMS terms for $\widehat{^{14}C}$ (one equation for each box). We derived transport parameters A, B, K_{US}, K_{UM} and K_H with air-sea $\Delta^{14}C$ exchange rates g_U and g_S for the U and S boxes respectively as inputs. All possible combinations of values (with a step size of 0.01 myr^{-1}) for g_U and g_S were applied to derive the values for transport parameters A, B, K_{US}, K_{UM} and K_H. Subsequently, g_U and g_S were constrained in a two-step procedure. First, all combinations were determined which result in transport parameters in the literature range in Table 5. Finally, the combination giving the most realistic NO_3, PO_4, and O_2 distributions (closest to observations) was chosen for the experiments in the main text (Fig. 8). This will be clarified in Appendix D of the revised ms.

Comment: Is there any evidence that the denitrification rate is in fact slower under suboxic conditions that conventional parameterization of biogeochemical models suggest (other than it giving improved model results)? What was the justification used in Schmittner et al.
Response: We did not find the justification in the Schmittner et al. [2008] paper, but there are both observations and models indicating a slower remineralization rate under suboxic conditions [Liu and Kaplan, 1984, Devol and Hartnett, 2001, Van Mooy et al., 2002]. We had already addressed this topic in the original ms (P11106 L12–15), which will be amended in the revised ms.

Comment: The paper presents the 7 main model configurations summarized in table 4, but in between other experiments with sensitivity to different parameters are also described in the result section and a couple more appear in the discussion. The paper would be easier to read if these runs were described separately from the runs in table 4, for example under a sub-heading "3.3 Sensitivity runs".
Response: We agree that the ms structure was somewhat confusing. We will improve it in the revised ms in response to this comment together with the comments from the other reviewer.
We will remove the STD configuration from the revised ms, because it contributes nothing to our conclusion, and rename the QM configuration from the original ms as the STD configuration in the revised ms. We will choose the new STD, RD, VIDRD and OBRD configurations as the main configurations, and mainly describe and discuss their results in the main text, since these are the configurations that illustrate our conclusions. We will add a subsection "3.3 Model sensitivity experiments", where we will summarise all model sensitivity experiments. The VD, VDRD, VID and OB configurations will now be described as sensitivity configurations briefly in Appendix E of the revised ms. Accordingly, Figure 2 and Figure 3 will also be replaced by Figures. 7 and 8 of this response letter.
We will also include several more summary sentences and make some statements more specific in order to clarify the role of each model configuration and sensitivity experiment. These are:
1, P11101 L14 "Sensitivity experiments are also performed with a configuration where N_2 fixation is inhibited by NO_3^-, but overall results are found to be virtually unchanged (Appendix D).".
will be **reworded to**: "Sensitivity experiments are also performed with a configuration where nitrogen fixers preferentially use nitrate when available and cover only the residual nitrogen demand via N_2 fixation, denoted as facultative N_2-fixation, but overall results are found to be virtually unchanged (Appendix B)."

2, P11103 L23:"In order to investigate the relationships between the different biotic and physical processes and the nitrogen cycle in an OMZ, we introduce eight additional model configurations (Table 5)"
will be **reworded to**: "In order to investigate the sensitivity of the nitrogen cycle in an OMZ to the different biotic and physical processes, we introduce seven additional model configurations. The main differences to the STD configuration are shown in Table 5."

3, "Two sensitivity experiments are performed for each of the VID and OB configurations to explore possibilities for preventing NO_3^- depletion in the OMZ: (a) different reduced remineralisation rates (f_{UM}) and (b) facultative N_2-fixation (see Appendix E)." will be **added** to P10L25–L27 of the revised ms.

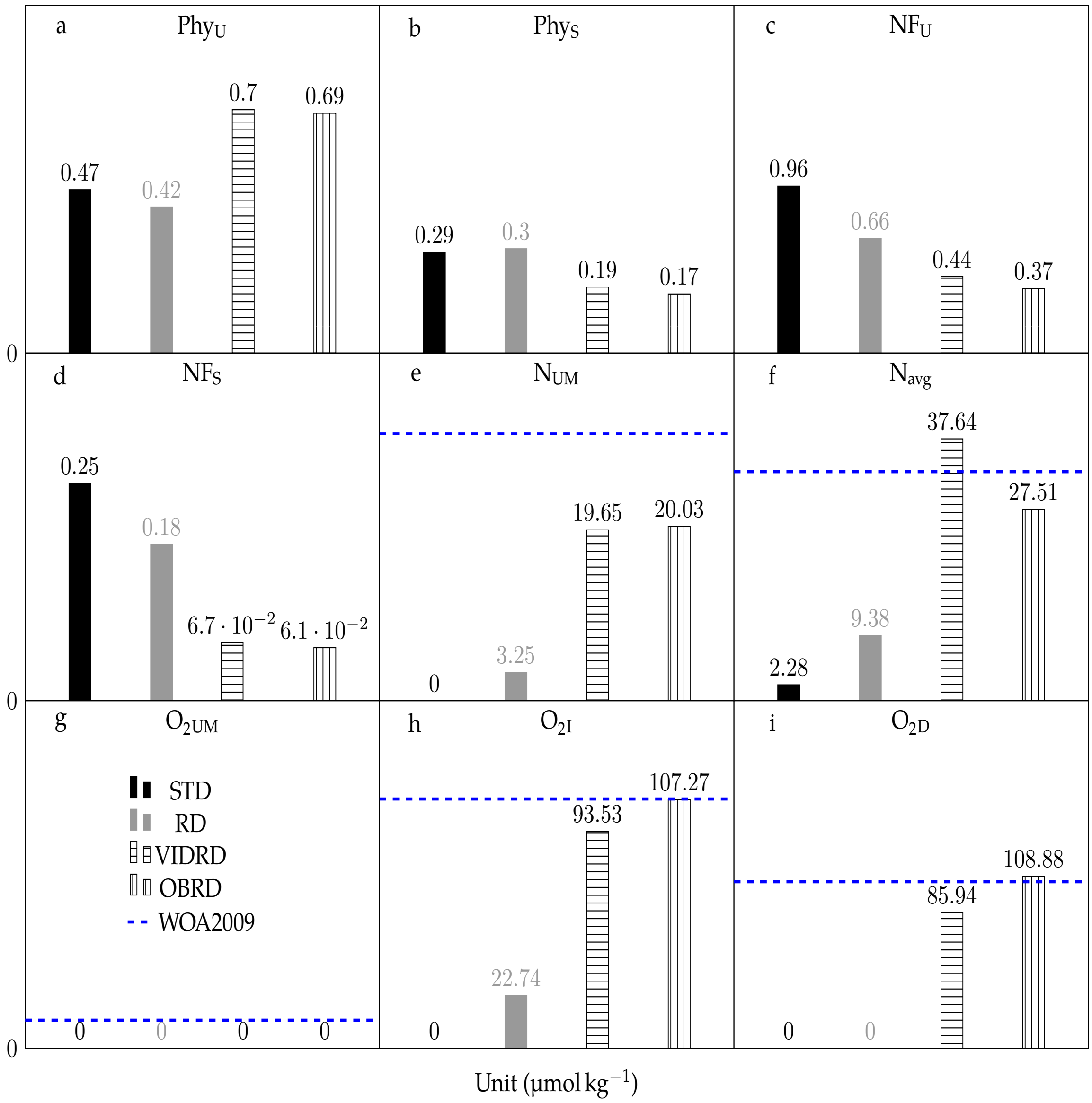


Figure 7: Simulated steady-state phytoplankton, nutrient and oxygen concentrations for the main model configurations defined in Tables 3 and 4. Each panel uses linear scale of the y-axis starting at zero. Dashed blue lines represent the average of the WOA2009 data of the corresponding boxes. There are no data for Phy_U, Phy_S, NF_U and NF_S.

4, P11105 L4–L11 will be **reworded to**: "For the OBRD configuration, three sensitivity experiments are performed to investigate our model sensitivity to variable physical transports and biogeochemical tracer concentrations: (1) The mixing rate with the southern boundary, K_H, is reduced for individual tracers (nutrients, oxygen) or combinations thereof from full rates to zero. (2) Simulations are repeated with individual circulation parameters varied by ±10 %, ±20 % and ±50 %, respectively, to explore the sensitivity with respect to the circulation parameters of the box model. (3) The sensitivity of NO_3^- and O_2 concentrations in the OMZ to different physical parameters derived from variations of the $\Delta^{14}C$ data and O_2 concentrations in the U-box is also examined."

5, P11105 L20 after "...exported organic matter." We will **add**: "The results for biogeochemical tracer concentrations of the STD, RD, VIDRD and OBRD configurations are shown in Fig. 2, since they are the main configurations that illustrate our conclusions, while those for the VD, VDRD, VID and OB configurations are shown in Fig. 8 and described in Appendix E, because these sensitivity configurations do not contribute significantly to explaining the existence of high NO_3^- concentrations

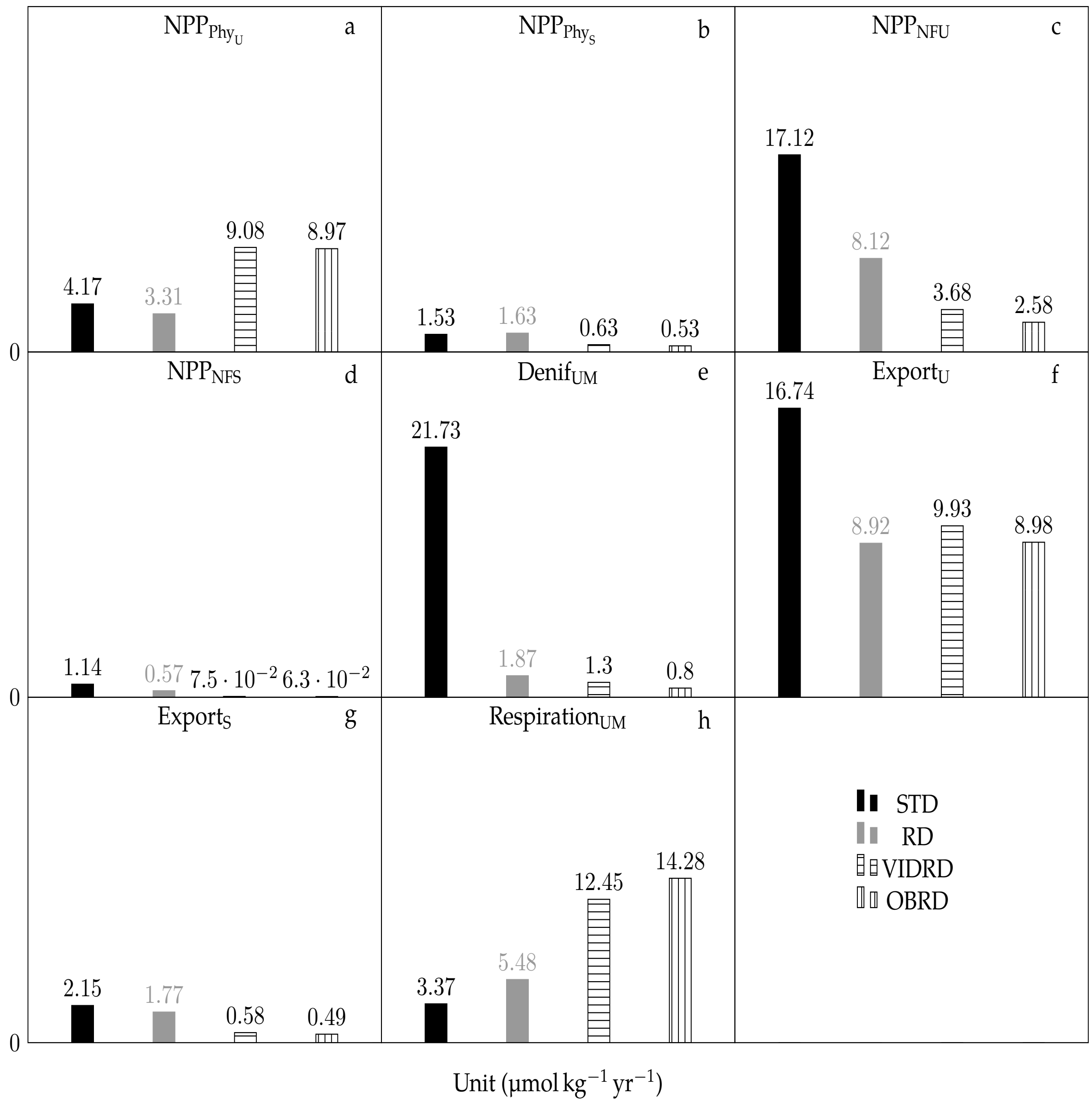


Figure 8: Simulated steady-state biogeochemical fluxes for the main model configurations.

Table 1: Phosphate concentration of each box for both models and WOA2009 data.

Box \ Configurations	STD	QM	RD	VDRD	VIDRD	OBRD	WOA2009
U	0.15	0.044	0.021	0.0096	0.012	0.0093	1.27
UM	3.22	3.22	1.73	1.80	1.92	1.73	2.53
S	0.13	0.0055	0.0037	0.0012	0.0012	0.0011	0.51
I	1.62	1.58	1.30	0.97	1.03	0.86	1.65
D	2.77	2.79	2.88	2.96	2.95	2.29	2.76

in the OMZ. ".
Afterwards, a new paragraph is started with "In the STD configuration,...".

6, P11107 L5:"Several sensitivity experiments..." will be **reworded to**: "Two sensitivity experiments..."

7, P11108 L3 **reworded to**: "For the biogeochemical fluxes, we focus on the STD, RD, VIDRD and OBRD configurations (configurations in bold in Table 5), since they show most clearly which mechanisms might be responsible for preventing NO_3^- exhaustion in the OMZ (Fig. 4)."

8, P23 L25–L27 and P24 L1–L5 in the revised ms, will be **added**: "Two further sensitivity experiments were performed for each of the VID and OB configurations to explore how NO_3^- depletion in the UM box can be prevented. (1) Decreasing the fraction of export production remineralized in the UM box (f_{UM}) from 70 % to 56 % makes NO_3^- persist in the UM box. Together with the 20 % remineralization in the U box, this implies that 76 % of the export production is remineralized in the upper 500 m of the ocean. However, the resulting NO_3^- concentration in the UM box is far below the literature range of about 15 to 40 μmol L^{-1}. (2) Facultative N_2-fixation inhibits nitrogen fixation in an environment with high NO_3^- concentrations, but fails to prevent NO_3^- depletion in the UM box. ".

Comment: Comparing model results to existing literature should be done in the discussion section (second paragraph p11109).
Response: We will move this paragraph to the discussion section of the revised ms.

Comment: It wasn't immediately clear to me that 'ventilation' meant that only oxygen would be exchanged with the SO, so it took me a while to figure out the difference between VID and OB, please state this clearer.
Response: The differences between the configurations are shown in Table 3. We will address it more clearly in the revised ms.

Comment: Show how the model phosphate compare to WOA2009.
Response: The comparison of model and WOA2009 phosphate concentrations is shown in Table 1 of this response letter. The surface phosphate concentrations for all the model configurations are much lower than those for the WOA2009 data, because the top 100m is assumed to be the euphotic zone in our model, but the depth of the euphotic zone is usually shallower than 100m in the ocean. The reason of our phosphate inventory of the model domain being lower than the WOA data in the OBRD configuration is that PO_4^{3-} is lost by mixing through the boundary with the southern subtropical ocean. However, the simulated surface phosphate concentration being lower than the observations seems to be a general problem of box models (see, for example, Panel (b) of Fig. 4 in Tyrrell [1999]).

Comment: P11108, L4 mention which runs that are studied rather than refer the reader to figure 3.
Response: We will **reword** this **to**: 'For the biogeochemical fluxes, we focus on the STD, RD, VIDRD and OBRD configurations, since they show most clearly which mechanisms might be responsible for

preventing NO_3^- exhaustion in the OMZ.

Comment: Table 4: add a short description of each parameter.
Response: We have explained each parameter in Table 5 already. We will **add** the following note to the caption of Table 4 : The detailed explanations for these parameters are given in Table 5.

Comment: Table 6: Are the models that are being compared also box models and are they configured for the same OMZ region?
Response: Mills and Arrigo [2010] is a box model for the OMZ of Eastern Tropical South Pacific. Kalvelage et al. [2013] is a reaction–diffusion model to estimate the nitrogen fluxes of the OMZ of Eastern Tropical South Pacific. We will indicate this in the caption of Table 6 in the revised ms as: "a) Reaction-diffusion model for the ETSP OMZ; b) Box model for the ETSP OMZ.".
Note: We will correct the export production of Kalvelage et al. [2013] to1.85 $\mu mol\,N\,kg^{-1}\,yr^{-1}$ in Table. 6.

Comment: Figure 2: I suggest indicating the WOA2009 level by a horizontal line rather than an extra bar.
Response: We agree with this suggestion and the new figure is shown here (Fig. 7 of this response letter).

Comment: Figure 4: This figure has too many panels, the text is so small it is almost unreadable. I do not understand the significance of the separate columns from the figure labels.
Response: We now enlarge the font in the legend and modify the caption for this figure (Fig. 9 of this response letter). We will separate the figure and caption into 2 pages, which will make the figure larger and more readable in the revised ms. We also remove the two columns named "O_2 and NO_3^-" and "O_2 and PO_4^{3-} ", since they produce quite similar results with the other two columns. The caption of this figure will be **reworded** as shown in Fig. 9 of this response letter.

Comment: Figure 5 - label: suggest to change "for different" to "to".
Response: Thanks! It will be changed in the revised ms.

Comment: Figure 6: It is hard to see the '*' on top of the x-axis.
Response: We have changed the location of the x-axis and then the '*' are more visible now (Fig. 10 of this response letter).

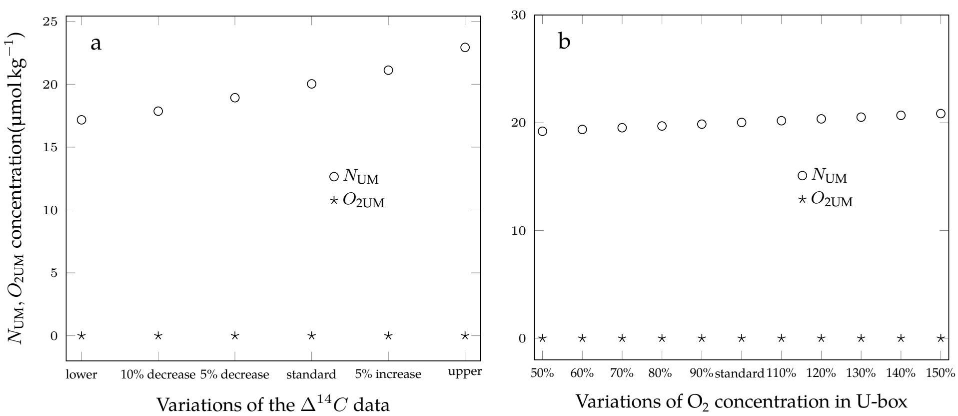


Figure 10: NO_3^- and O_2 concentrations in the OBRD configuration for different physical parameters derived from variations of the $\Delta^{14}C$ data (panel a) and O_2 concentration in the U-box (panel b). a: Decrease and increase mean that $\Delta^{14}C$ values in all boxes are reduced or increased simultaneously. b: Values of the x-axis denote the variations of O_2 concentration in the U-box relative to the standard. Standard run in each figure is the OBRD configuration with physical parameters defined in Table 4.

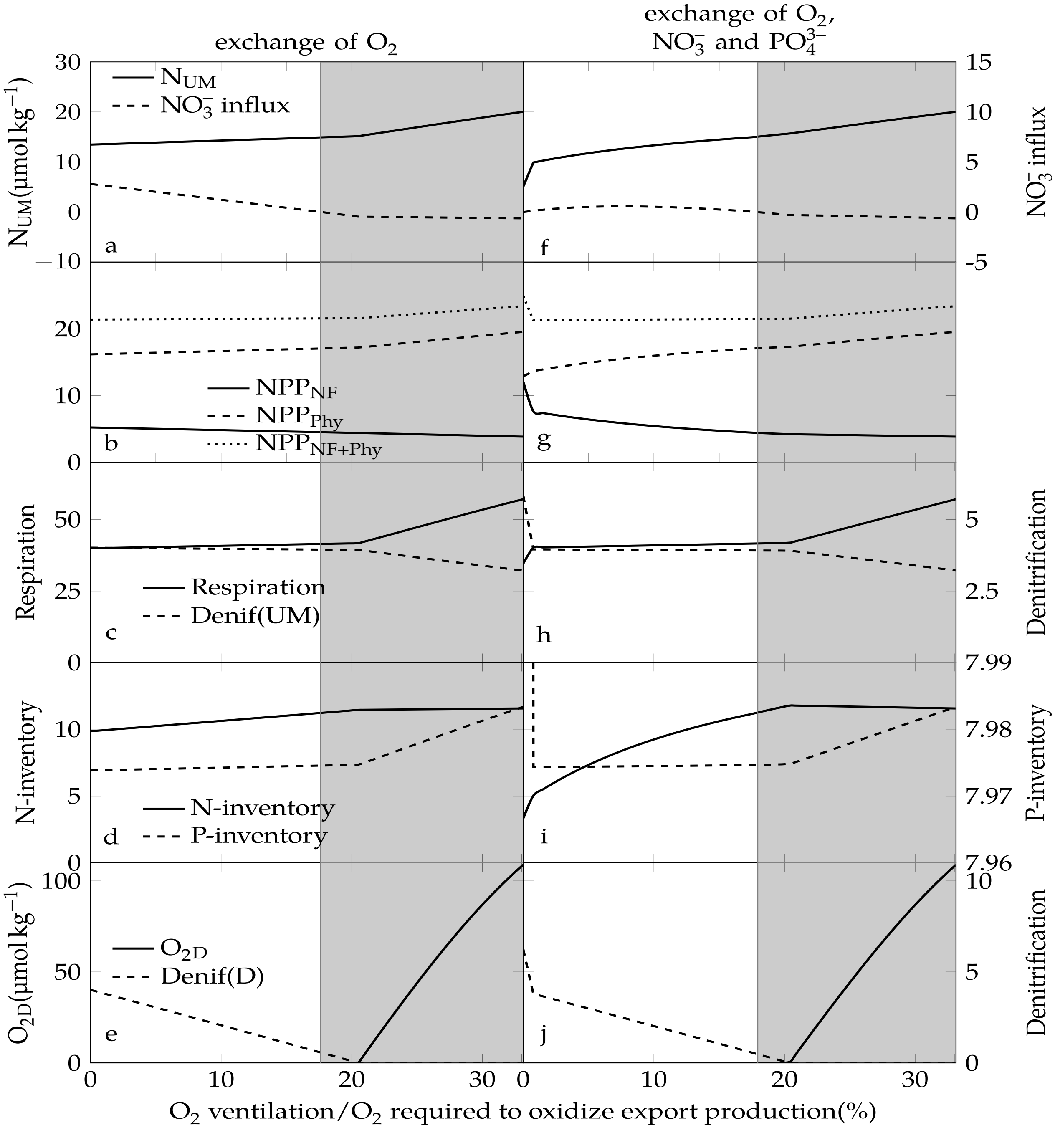


Figure 9: Dependence of biogeochemical processes on the exchange of O_2, NO_3^-, and PO_4^{3-} with the subtropical ocean through the southern boundaries of the I and D boxes. The x-axes indicate the contribution of O_2 supplied from the subtropical ocean relative to that required to oxidize all export production from the surface ocean (boxes U and S). (a–e) only O_2 is exchanged through the southern boundaries; (f–j) exchange of O_2, NO_3^-, and PO_4^{3-}. N_{UM} is NO_3^- concentration in the UM box and NO_3^- influx is the NO_3^- flux through the southern boundary (positive into model domain). NPP_{Phy}, NPP_{NF} and NPP_{NF+Phy} are net primary production by ordinary phytoplankton, nitrogen fixers, and the sum of both in the surface ocean. Respiration and Denif (UM) represent O_2 consumption by aerobic remineralization and NO_3^- removal by anaerobic remineralization, respectively, in the UM box. N-inventory and P-inventory are the total nitrogen and phosphorus inventories in the model domain, including all organic and inorganic species. O_{2D} and Denif (D) represent O_2 concentration and NO_3^- removal by anaerobic remineralization in the D box. Units of all variables are 10^{11} μmol yr^{-1} m^{-1} except for N_{UM} and O_{2D}, which are given in μmol kg^{-1}. The shaded area denotes the parameter range for which the model domain is a net source of NO_3^-.

Comment: Figure 7- label. Add "as a function of the oxygen concentration in the D box" to the end of the first sentence.
Response: This will be included in the revised ms.

Comment: Figure 8 - what is meant by "all combinations of physical transport parameters in the literature range" (this is also mentioned in the text, but it is still unclear), perhaps I missed it, is this range indicated anywhere in the paper?
Response: This is related to how we have determined the physical transport parameters. As we have described in Appendix C of the original ms and the above answer to 'how to determine g_U and g_S', we have tried all combinations of values for g_U and g_S, each of which defines one set of physical transport parameters. Then, g_U and g_S were constrained in a two-step procedure. First, all combinations are determined which result in transport parameters within the literature range, which are shown in Table 5. Secondly, the combination giving the most realistic NO_3^-, PO_4^{3-}, and oxygen distributions is chosen for the experiments (Table 4).
We will **reword** "all combinations of physical transport parameters in the literature range" **to** "all combinations of g_U and g_S resulting in all transport parameters being inside the literature range as given in Table 5" to clarify this point in the revised ms. In Fig. 8 we show the set of parameters that we have chosen for all the model configurations, which is the second step to determine our physical parameters.

Comment: Figure 9: with only small differences between this and the original run, perhaps this figure can be omitted?
Response: Yes, only small differences can be identified after including the Schmittner formulation for NF. We will remove it from our ms.

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